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Chapter

Influence of Temperature and Storage Systems on Post-Harvest Losses of Maize Varieties Cultivated at Alibori in Northern Benin

Corinne M. Anagonou, Roland Dossou, Anicet G. Dassou and Alexandre Dansi

Abstract

Majority of post-harvest losses of several maize varieties observed in various storage systems in northern Benin are mainly caused by storage insects due to changes in climatic parameters. The objective of this study is to evaluate the levels of insect pest infestation of three maize varieties stored in storage systems at different temperature. In 18 villages at Alibori, maize farmers were surveyed through a participatory research approach and their storage structures were also visited. The temperature of all storage structures were noted. Weight loss of samples, numbers of *Prostephanus truncates*, *Sitophilus zeamais* and perforated grains were evaluated. In total, three maize varieties and three different groups of storage systems were identified during field observations. All the three maize varieties stored in the first storage systems group built with plants were less infested and had acceptable nutritional quality than the maize grains stored in the second group built in banco and third group built with tarpaulin. In these storage systems, the yellow maize variety was the most attacked, followed by the white maize variety and finally the mixed color of yellow and white maize variety the less attacked. Effective post-harvest management of stored products requires clear monitoring criteria of climatic parameters and effective implementation of abiotic and biotic factors.

Keywords: maize, storage system, insect pests, post-harvest losses, temperature, Alibori

1. Introduction

Maize is the basic food in most of developing countries [1]. Maize is also important for commercial transactions [2]. To increase agricultural income, have good quality of seeds and ensure permanent availability of maize in the market over a long period, farmers use different post-harvest storage systems to conserve the maize. In Eastern Senegal, the storage of maize grains is done in bags, racks, granaries, barrels, shops and others [3]. In Tanzania, in polyethylene bags, granaries, cans and other plastic containers are also used for storing maize [4]. In Benin, maize is stored in traditional granaries built from straw, bamboo, branches or reeds used to store spathed or despathed ears; in earth granaries for maize grain storage;

in artisanal cribs; in stores for large maize farmers (often in 100 kg bags). [5] had to distinguish two forms of granary: the traditional granaries (the type “Ago” and the type “Ava”) and improved granaries made in plant materials and earth closed.

Majority of these storage systems have enough post-harvest losses often recorded in stored maize. More than 30% of grain crop harvests including maize are lost during storage in sub-Saharan Africa [6]. Maize post-harvest losses in tropics in general [7] and especially in Benin [8] can reach 40% after five months of storage. These losses are mainly due to the pests attack associated with the variation of temperature in the granaries. The most common storage insects are *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae), *Rhyzopertha dominica* (F.) (Coleoptera: Bostrichidae), and the *Sitophilus zeamais* (Coleoptera: Curculionidae) [9–11]. From these storage insects, *Prostephanus truncatus* (Horn) and *Sitophilus zeamais* (Motschulsky) are the major insects observed in maize stocks [8, 12]. In rural areas where conservation techniques are poorly developed, *S. zeamais* can cause post-harvest losses of up to 90% for five months of storage [13, 14]. They cause damage including weight loss, a decrease in grain quality [15] and sometimes a loss of germination [16].

Defective storage structures with uncontrolled climatic conditions increase the abundance of storage insects and their damage in stored products. Many traditional granaries are not well ventilated and maintained in optimal temperature for the development of storage insects. Keeping maize grains in storage structures with low temperature and humidity helps to reduce the damage caused by storage insects [17]. Few studies emphasized on the temperature and humidity at which the grains of maize must be stored in storage structures to reduce the damage of storage insects.

Therefore, this study was conducted in Alibori region to identify the endogenous storage systems used by farmers for maize conservation and to evaluate the losses caused by these storage structures in various climatic conditions. The main objective of this research is to evaluate the influence of maize storage systems with different temperature on maize post-harvest losses in Alibori Region. Specifically, the present study aims to: (i) Assess the effect of yellow, white and mixed color of yellow and white maize varieties on post-harvest losses to determine which maize varieties cultivated in the study area are more resistant to insects attack; and (ii) Determine the influence of internal temperature inside storage structures on maize post-harvest losses to suggest to farmers the best post-harvest structures adapted to the better maize conservation.

2. Methodology

2.1 Study area

Alibori is one of Northern Benin region. It is located between 11°19′ north latitude and 2°55′ east longitude. It is bordered in the North by the Republic of Niger, in the North-West by the Republic of Burkina Faso, in the East by the Federal Republic of Nigeria, in the West by the Atacora and in the South by the Borgou Region (**Figure 1**). The daily temperature varies between 22° to 40°C. With an area of 26,242 km^2 (23% of the national territory), Alibori is subdivided into six Municipalities which are Malanville, Karimama, Ségbana, Gogounou, Banikoara and Kandi, making up 41 districts and 229 villages. Its population is estimated at 867,463 inhabitants. The climate is of the Sudanian type in its southern part and Sudano-sahelian in its northern part (Karimama and Malanville). There is only one season of rain which lasts between 5 and 6 months with an oscillating rainfall

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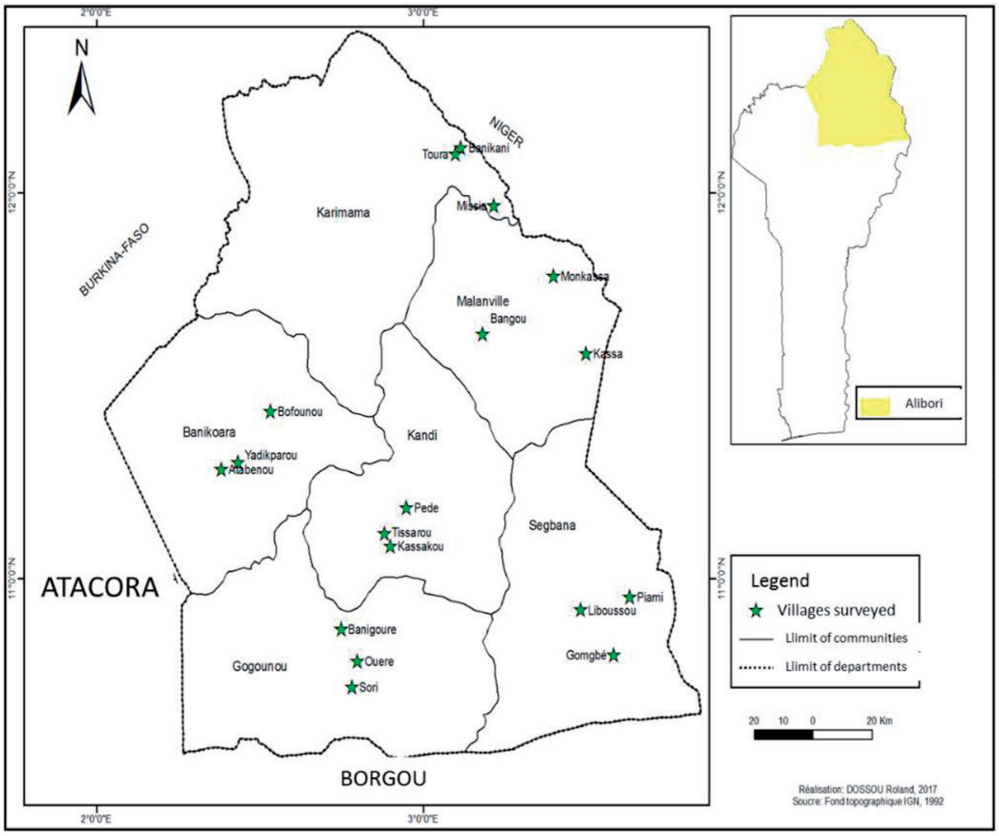

Figure 1.
Presentation of the study area and geographical position of the surveyed villages.

between 700 and 1200 mm. The vegetation is composed of a sparse shrub savannah, dominated by thorny trees, including *Acacia seyal* and *Acacia siebenona* in the north; and a grassy savannah heavily degraded to the South.

2.2 Data sampling

Data were collected in 18 villages during the months of April to June at the different maize storage sites through the application of participatory research tools and techniques such as direct observation, individual interviews and field visits using a questionnaire [18]. To identify the storage structures in the study area, farmers were asked to give the name of the storage structures or storage used by their household. Subsequently, these storage structures were visited and photographed for better description. Probe Thermometers were introduced at different places in these maize storage structures to note daily the internal ambient temperature. To assess the maize post-harvest losses caused by storage insects in the study during storage, approximately 1 kg of maize grains and maize corns of three varieties (white, yellow and white-yellow) was collected from all storage structures. A total of six samples including three varieties in the form of grains and also three in the form of corns were collected in each structure. The three storage structures such as granaries in banco, granaries in Plant Materials and conservation with Tarpaulin were used in the study. Daily temperature values were recorded in each storage structure during survey periods using metal probe thermometers. In each storage structure, probe thermometer was placed in three different locations such as at the roof, at the base and on side. The daily temperature was obtained by calculating the average value of the three temperature measurements made on each type of granary. All farmers store their products during the same period after the rainy season. Concerning the evaluation of storage losses, the initial and final weight of maize samples, the number and weight of the perforated maize grains were evaluated in the laboratory. Insect densities were calculated per kilogram of maize grains.

2.3 Data analyses

We used a Generalized Linear Model (GLM) with the family binomial and Analysis of Variance (ANOVA) to determine the effects of storage structures, and forms of conservation of maize varieties in (i) proportions of pest damage and (ii) densities of *Prostephanus truncates* and *Sitophilus zeamais*. The same analyzes were performed using the Generalized Linear Model (GLM) with the family Poisson and Analysis of Variance (ANOVA) to determine the effects of temperature of different storage structures on the masses of grains damaged. The test of Tukey HSD was used to determine the difference of masses of grains damaged between the storage structures. All the analysis was performed with the statistical software R version 3.4.2 [19].

3. Results

3.1 Densities of storage insects and effects of storage structures, and maize varieties on the insect pest damage

Prostephanus truncatus and *Sitophilus zeamais* were the two most abundant pests in maize stocks and their densities varied by communities ($P < 0.00001$). The density of *Prostepahanus trucatus* alive was higher in Malanville followed by Kandi and then the other municipalities. In contrast, the density of *Sitophilus zemais* was higher in Segbana followed by other municipalities (**Table 1**). Concerning the losses in number of damaged maize grains, the damage is observed much in Kandi followed by Malanville.

Even, all farmers noted that *Prostephanus truncatus* and *Sitophilus zeamais* were both major storage insects damaging the maize in post-harvest systems in study areas and it was confirmed by our observations. Post-harvest losses by volume were the most identified by the majority of farmers in all the study communities compared to post-harvest losses by weight. Municipalities of Gogounou and Kandi had the highest percentages of farmer responses in terms of volume and weight. Losses (**Figure 2**).

According to maize varieties, a significant effect was noted in maize weight loss and was positive for the yellow variety showing that post-harvest losses were enormous in this variety. A negative effect was observed for the mixed color of yellow and white maize variety showing that losses were reduced in this variety (**Table 2**). The boxplot carrying out the relationship between the maize varieties and weight of damaged maize grains by storage insects has shown that the yellow variety was the most attacked, followed by the white variety and finally the mixed color of yellow and white variety was the least attacked (**Figure 3**). The analysis of variance (ANOVA) showed a significant effect of the structures and forms of storage on the number of damaged maize grains ($Df = 2$, $P < 0.00001$). The test of Tukey HSD showed a significant difference only between the three maize varieties ($P < 0.00001$) and the three storage structures ($P < 0.00001$) for the infestation percentages.

3.2 Effects of temperature within different storage structures on the weight of grains damaged

The temperature of different storage structures had a significant and positive effect on damaged maize kernels weight ($P < 0.00001$, z-value = 6.21). Granaries built in plant materials conserved a low temperature and presented the low

Pests/damages	Banikoara	Gogounou	Kandi	Karimama	Malanville	Segbana
Live Prostephanus truncatus	3.3 ± 0.08	4.12 ± 0.13	6.5 ± 1.99	3.5 ± 0.04	9.5 ± 0.68	5.57 ± 2.13
Dead Prostephanus truncatus	0.4 ± 0.04	0.25 ± 0.06	0.6 ± 0.01	0.00 ± 0.00	0.00 ± 0.00	0.28 ± 0.08
Live Sitophilus zeamais	2.1 ± 0.027	3.5 ± 0.32	1.5 ± 0.76	0.5 ± 0.01	0.5 ± 0.06	11.57 ± 0.018
Dead Sitophilus zeamais	0.8 ± 0.122	0.125 ± 0.04	0.1 ± 0.01	0.00 ± 0.00	0.00 ± 0.00	2.14 ± 0.47
Number of damaged maize grains	3.4 ± 0.12	4.125 ± 0.27	6.8 ± 0.18	0.50 ± 0.00	4.62 ± 0.13	4.14 ± 2.54
Weight of damaged maize grains	0.77 ± 0.34	0.63 ± 0.07	1.24 ± 0.09	0.17 ± 0.03	1.21 ± 0.17	0.96 ± 0.058

Table 1.
Densities of storage insects and damaged maize grains according to study communities.

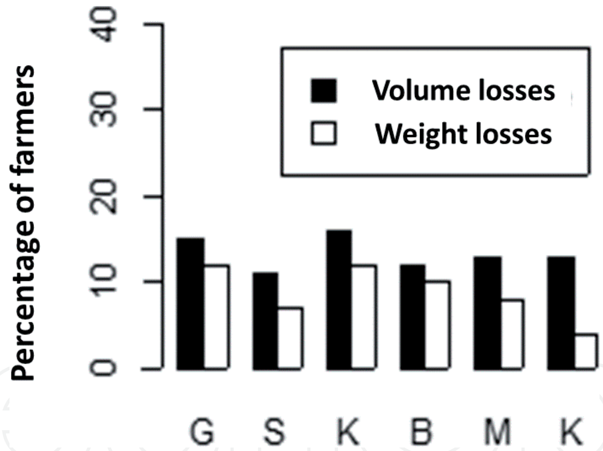

Figure 2.
Frequency of farmers listing the different types of post-harvest losses by communities. G, Gogounou; S, Ségbana; K, Kandi; Banikoara M, Malanville and K, Karimama.

Damage	Maize varieties	Df	Estimates	z-value	Pr (>|z|)
Number of damaged maize grains	Yellow	2	−1.5268	−4.270	<0.00001
	Mixed color (yellow- white)	2	−0.0826	−0.090	0.928 ns
	White	2	−1.0306	−0.563	0.574 ns
Weight of damaged maize grains	Yellow	2	1.46634	18.315	<0.00001
	Mixed color (yellow- white)	2	−0.77319	−2.771	0.005582
	White	2	0.64388	3.360	0.000778

Table 2.
Effect of maize varieties on the number and weight of damaged maize grains.

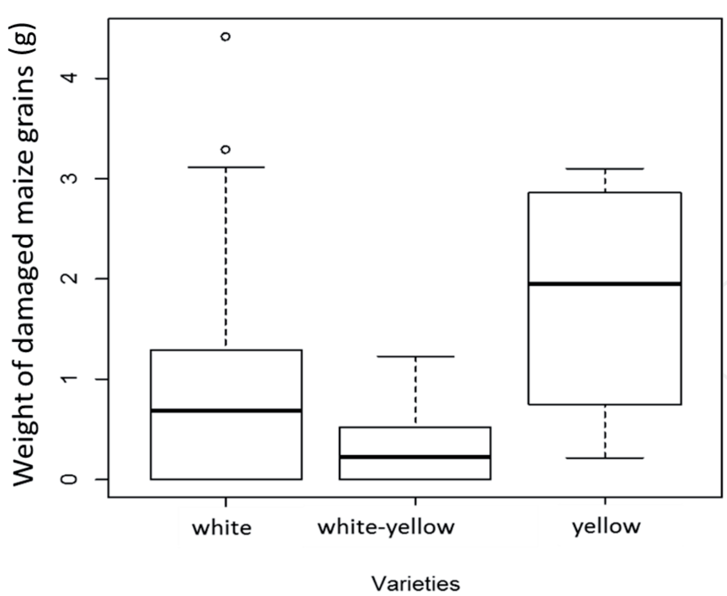

Figure 3.
Boxplot showing the level of weight loss according to the maize varieties.

damaged maize grains weight while the storage structures made with the tarpaulin protection presented high temperature and infestation (**Figures 4** and **5**). The test of Tukey HSD showed a significant difference only between the three storage structures (P < 0.00001) for the temperature.

Figure 4.
Some storage structures of maize built in study areas.

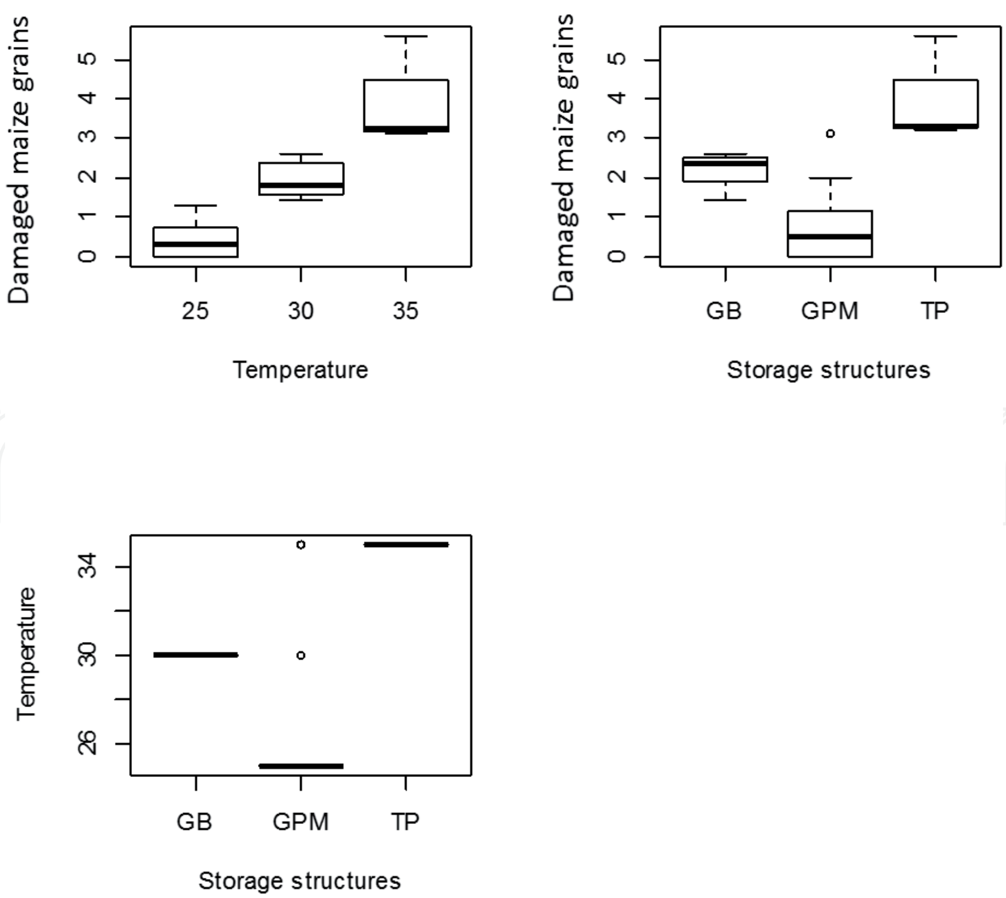

Figure 5.
Relationship between temperature of different storage structures and maize post-harvest losses. GB, granaries in banco, GPM, granaries in plant materials; TP, conservation with tarpaulin protection.

4. Discussion

4.1 Densities of storage insects and influence of storage structures and maize varieties on the insect pest damage

The main pests detected in laboratories on maize samples collected in the study area were *Prostephanus truncatus* followed by *Sitophilus zeamais*. Similar study conducted by [3, 4, 6, 20] had already recognized these insects as insects pests with huge losses of maize stocks. The abundance of certain storage insects would have a significant effect according to municipalities. This variation in insect densities can be justified by the singularity and the variation of the storage systems from one community to another. These recorded weight losses can also be justified by the use of traditional loft in banco (in Segbana), uncemented chamber (in Malanville) and bags. The post-harvest losses evaluated in terms of the number of damaged grains are more observed in maize samples from Gogounou Malanville and Segbana communities than in other communities. These represent the major production areas of maize in Alibori region and therefore include many traditional storage systems.

Additionally, the results obtained show that during maize storage, farmers have more post-harvest losses in volume than post-harvest losses in weight. This can be explained by the fact that storage structures used in study areas favor the loss of volume more than the weight losses. Statistical analyzes revealed that the form of maize stored has no significant effect in the post-harvest losses. This shows that all the storage systems encountered in the study environment have a storage defect due to their construction.; Only the level of insects attack varies from one structure to another [21]. The result are consistent with those of [3] in Senegal which reported that post-harvest losses of corn are independent of the mode or form of maize stored.

Furthermore, statistical analyzes revealed that post-harvest losses evaluated by weight do not depend on the communities. This can be explained by the fact that all the maize samples collected in all the villages of the six Municipalities are sensitive to post-harvest losses evaluated by weight [22]. These recorded weight losses can also be justified by the use of traditional granaries in banco, uncemented storage and bags. The results also showed that the yellow maize variety favors the development of storage insects as the white maize variety. It means that insects attack differs according to the maize varieties. First of all, the yellow variety wasthe most damaged followed by the white maize variety and the mixed color of yellow and white maize variety respectively.

4.2 Effects of temperature within different storage structures on the weight of maize grains damaged

The results showed that in the average temperature of 30–35°C in storage structures, the damage of storage insects on stored maize is high. This shows that these temperatures are optimal for rapid reproduction of storage insects in storage systems in the study area. Storage structures with internal temperatures of 30–35°C may be improved to reduce the damage of storage insects to the stored maize [17]. Other studies have shown that an average temperature of 30°C is optimal for the proliferation of storage insects and that above 35°C the temperature becomes lethal to these insects [12, 17, 23]. The use of tarpaulins and banco storage structures should be discouraged to producers for better conservation of maize. On the other hand, the results showed that at an average temperature of 25°C, maize grains were well preserved in storage structures made with plant materials and has low infestations. Further studies have been conducted to show that low temperature (<15° C) increases mortality and reduces oviposition and fecundity of *S. zeamais* and *S. oryzae* [24, 25]. Storage structures made from plant materials have good aeration and maintain a low internal temperature reducing the development of storage insects.

5. Conclusion

The different maize storage systems encountered in the study area have influence on post-harvest losses. Although grain storage is the preferred mode in the study area, it is more attacked by storage insects than corn on the cob. In addition, the 100 kg bags and banco granaries used by corn farmers in the study area were the storage structures that favored the attack of storage insects. The yellow variety was the most attacked followed by the white variety and the yellow-white respectively.

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Conflict of interest

The authors declare that they have no conflict of interest.

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